



NASA STTR 2012 Phase I Solicitation

T4.03 Extreme Particle Flow Physics Simulation Capability

Lead Center: KSC

Advanced computer modeling software is sought to provide the ability to predict the flow of granular materials in space and/or planetary environments. Proposals are sought for software capable of handling one or more of the following applications in one or more relevant environments for space exploration:

- Rovers driving on planetary regolith.
- Rocket engines blowing planetary regolith.
- Excavators and resource extraction systems moving and conveying planetary regolith.
- Technologies that burrow or drill into planets and asteroids for scientific access.
- Transport of granulated metal hydrides as hydrogen fuel systems.
- 3-D printing technologies that use powders in space manufacturing.

The relevant environments, or "extreme environments," are the environments encountered in space exploration but not normally encountered in terrestrial industry. These may include supersonic gas flow, rarefied atmospheres, low gravity, or zero gravity, where we have less terrestrial experience in the behaviors of granular flow.

This modeling capability will be useful as part of the engineering design and checkout process for aerospace systems, notably the technologies that will interact with planetary soil. The technologies that are sought are different than prior state-of-the-art (SOA) in granular modeling insofar as prior SOA often utilized ad hoc algorithms, empirical relationships, and "rules of thumb" to estimate granular behavior, and relied on "tweaking" model parameters until the modeling approximated experimental data over a limited range of application. (Granular flow is challenging due to meso-scale granularity that produces a bewildering array of emergent, macro-scale phenomena.) Prior SOA was therefore not truly predictive and therefore of limited power, but it was useful for modest extrapolation around a range of behaviors that has been previously validated by experiment. In contrast, advances in granular physics theory over the past 5 years are surprisingly far ahead of expectations and it is now possible to develop new modeling methods that are truly predictive for the previously unpredictable regimes of solid-like, fluid-like and gas-like flow of granular materials integrated with gas flow and mechanical devices, including extreme environments (rarefied/supersonic flow, planetary surfaces, etc.). While it is still too early to expect a software package to be capable of modeling all granular phenomena across all ranges of behavior and all environments, it is now possible to create software packages capable of handling one or more of the areas that are

important to NASA and necessary for NASA's mission.

Relevant advances in granular physics that may be incorporated into the new software may include (but are not limited to):

- Granular gas theory equivalent to Boltzmann's Transport Equation.
- Application of granular gas theory to continuous particle size distribution to predict transport coefficients.
- Successful prediction of dense flow as a function of particle shape.
- A useful technology will be one that can be applied in the real-world engineering design process for the design and checkout of NASA spaceflight technologies.